CLAIMS

1. A carbon-based thin film comprising:

columnar first phases that contain amorphous carbon and extend in a film thickness direction; and

a second phase that contains a graphite structure and intervenes between the first phases,

wherein at least one selected from the group consisting of the following a) to e) is satisfied:

a) the second phase contains more graphite structures per unit volume than the first phases;

b) a density of the second phase is larger than that of the first phases;

c) an electric resistivity of the second phase is lower than that of the first phases;

d) an elastic modulus of the second phase is higher than that of the first phases; and

e) in the second phase, a basal plane of the graphite structure is oriented along the film thickness direction.

2. The carbon-based thin film according to claim 1, wherein the first phases have an average size of 300 nm or less in an in-plane direction of the film.

3. The carbon-based thin film according to claim 1, wherein an average spacing between adjacent two phases selected from the first phases is 50 nm or less in an in-plane direction of the film.

4. The carbon-based thin film according to claim 1, wherein the second phase forms a network between the first phases.

5. The carbon-based thin film according to claim 1, further comprising at least one selected from the group consisting of hydrogen, nitrogen, boron, and silicon.

6. The carbon-based thin film according to claim 1, comprising:

a first region including the first phases and the second phase; and

a second region including:

columnar third phases that contain amorphous carbon and extend

in a film thickness direction; and

a fourth phase that contains amorphous carbon and intervenes between the third phases,

wherein at least one selected from the group consisting of the following f) to i) is satisfied:

f) the second phase contains more graphite structures per unit volume than the fourth phase;

g) a density of the second phase is larger than that of the fourth phase;

h) an electric resistivity of the second phase is lower than that of the fourth phase; and

i) an elastic modulus of the second phase is higher than that of the fourth phase.

7. The carbon-based thin film according to claim 6, wherein at least one selected from the group consisting of the following j) to k) is satisfied:

j) either one selected from the first region and the second region is a columnar region surrounded by the other region, and an average size in an in-plane direction of the columnar region is 100 nm or more; and

k) in a first in-plane direction, the first region and the second region have average sizes of two or more times larger than those in a second in-plane direction that is perpendicular to the first in-plane direction, and in the second in-plane direction, the first region and the second region are arranged alternately.

8. The carbon-based thin film according to claim 7, wherein the first region and the second region are strip-shaped regions.

9. The carbon-based thin film according to claim 1, comprising:

a first region including the first phases and the second phase; and

a second region including:

columnar third phases that contain amorphous carbon and extend in a film thickness direction; and

a fourth phase that contains amorphous carbon and intervenes between the third phases, wherein

a light transmittance in a wavelength range of 600 nm to 1100 nm in the first region is lower than that in the wavelength range in the second region.

10. The carbon-based thin film according to claim 9, wherein at least one

selected from the group consisting of the following j) to k) is satisfied:

j) either one selected from the first region and the second region is a columnar region surrounded by the other region, and an average size in an in-plane direction of the columnar region is 100 nm or more; and

k) in a first in-plane direction, the first region and the second region have average sizes of two or more times larger than those in a second in-plane direction that is perpendicular to the first in-plane direction, and in the second in-plane direction, the first region and the second region are arranged alternately.

11. The carbon-based thin film according to claim 10, wherein the first region and the second region are strip-shaped regions.

12. The carbon-based thin film according to claim 1, wherein T/W>10 is satisfied in which T is a thickness of the film, and W is an average spacing between adjacent two phases selected from the first phases in an in-plane direction of the film.

13. A process for producing a carbon-based thin film comprising the following steps of:

forming an amorphous carbon-based thin film that includes columnar first phases extending in a film thickness direction, and a second phase intervening between the first phases; and

forming a graphite structure at least in the second phase by supplying energy to the amorphous carbon-based thin film.

14. The process for producing a carbon-based thin film according to claim 13, wherein the amorphous carbon-based thin film is formed by a vapor phase deposition method.

15. The process for producing a carbon-based thin film according to claim 14, wherein the amorphous carbon-based thin film is formed by a physical vapor deposition method, and the deposition method satisfies at least one of a condition A that a substrate temperature is 773 K or less and a condition B that an atmospheric pressure is 1.33 Pa or more.

16. The process for producing a carbon-based thin film according to claim 14, wherein the amorphous carbon-based thin film is formed in an atmosphere

containing at least one selected from the group consisting of a hydrogen atom-containing gas and a nitrogen atom-containing gas.

17. The process for producing a carbon-based thin film according to claim 13, wherein the amorphous carbon-based thin film is supplied with energy by irradiating an electron beam.

18. The process for producing a carbon-based thin film according to a claim 13, wherein by supplying energy to the amorphous carbon-based thin film, more graphite structures per unit volume are formed in the second phase than in the first phases.

19. The process for producing a carbon-based thin film according to claim 18, wherein the amorphous carbon-based thin film is formed so that a density of the second phase is lower than that of the first phases and that a structural change of the second phase by supplying energy to the amorphous carbon-based thin film is made to occur more easily than the structural change of the first phases.

20. The process for producing a carbon-based thin film according to claim 13, wherein the amorphous carbon-based thin film is formed so that a density of the second phase is lower than that of the first phases, and the amorphous carbon-based thin film is supplied with energy so that, with a formation of the graphite structure, the density of the second phase is higher than that of the first phases.

21. The process for producing a carbon-based thin film according to claim 13, wherein energy is supplied so that at least one selected from the group consisting of the following a) to e) is satisfied:

a) the second phase contains more graphite structures per unit volume than the first phases;

b) a density of the second phase is larger than that of the first phases;

c) an electric resistivity of the second phase is lower than that of the first phases;

d) an elastic modulus of the second phase is higher than that of the first phases; and

e) in the second phase, a basal plane of the graphite structure is oriented along a film thickness direction.

22. The process for producing a carbon-based thin film according to claim 13, wherein the amorphous carbon-based thin film is supplied with energy by irradiating an electron beam with an intensity of $1 \times 10^{19}/cm^2 \cdot sec$ or less.

23. The process for producing a carbon-based thin film according to claim 13, wherein the amorphous carbon-based thin film is formed so that the second phase forms a network between the first phases.

24. The process for producing a carbon-based thin film according to claim 13, wherein the energy is supplied only to a portion of the amorphous carbon-based thin film.

25. The process for producing a carbon-based thin film according to claim 24, wherein an electron beam is irradiated onto a surface of the amorphous carbon-based thin film in a state that the surface is partially masked.

26. A member comprising a substrate and a thin film formed on a surface of the substrate, wherein the thin film is the carbon-based thin film according to claim 1.

27. The member according to claim 26, wherein the substrate is made of metal, semiconductor, ceramic, glass, or resin.

28. The member according to claim 26, further comprising an intermediate film arranged between the substrate and the thin film.

29. The member according to claim 26, wherein the thin film is formed on the surface of the substrate, and the surface is to be in contact with another member.

30. The member according to claim 26, wherein the member is usable as at least one selected from the group consisting of a sliding member, a molding die, and an electrical contact terminal.